Exploring the Impact of a Tabletop-Generated Group Work Feedback on Students' Collaborative Skills

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Abstract: This study explores the impact of a tabletop-generated feedback on student's collaborative skills over time. Twenty-one Computer Science students participated in a three-week experimentation. A two-group design was used to assess three dimensions of collaboration: contributions, communication and respect. While the experimental group was asked to solve a database design problem using a tabletop system and received human and automatic feedback afterwards, the control group was asked to use a paper-based approach for the same task and received human feedback only. Results showed no significant difference between both groups, neither in their levels of group work skills, nor in the students' self-perception of their group work skills Nonetheless, there was an improvement over the whole experience on the communication dimension on the experimental group. Likewise, both conditions showed a significant improvement on students' self-perception of their group work skills. In addition, a positive moderate correlation between the automatic and human assessment of students' contributions to group work was found. This confirms opportunities to further explore tabletop-based feedback for group work activities.

Keywords: learning analytics, tabletop systems, collaborative skills, reflection, self-perception

Introduction

Software design often demands Computer Science practitioners to successfully engage in face-to-face collaboration with peers, clients and stakeholders (Dekel & Herbsleb, 2007). Aware of this professional requirement, Computer Science programs regularly promote in-class studio-based group activities (Lee, Kotonya, Whittle, & Bull, 2015). Nonetheless, engaging in collaborative work does not necessarily lead to the development of group work skills (Dillenbourg, 1999); learning to collaborate often requires self-reflection prompted by on-time feedback (O'Donnell, 2006). Obtaining such feedback, however, is not always a straightforward task; time and attention constraints prevent educators to fully acknowledge individual's performance and needs (Zhang, Zhao, Zhou, & Nunamaker Jr., 2004). Within this context, exploring mechanisms to aid students' self-reflect on their collaborative skills becomes a relevant goal to pursue.

Previous work on multi-touch tabletops has shown this novel technology has a strong potential to strengthen students' group work skills by promoting communication (Buisine, Besacier, Aoussat, & Vernier, 2012), awareness of others (Falcão & Price, 2011) and equity of participation (Wallace, Scott, & MacGregor, 2013). Moreover, the ability of tabletops to seamlessly garner traces of students' interactions opens the possibility to timely deliver the feedback students require to engage in self-reflection (Al-Qaraghuli, Zaman, Olivier, Kharrufa, & Ahmad, 2011; Clayphan, Martinez-Maldonado, & Kay, 2013; Martinez-Maldonado, Dimitriadis, Martinez-Monés, Kay, & Yacef, 2013). In spite of the promising potential of tabletop-mediated classrooms, a deep understanding of its strengths and limitations requires studies to be carried out both over longer periods of time, and within real classroom settings where students perform tasks directly related to their interests (Xambó et al., 2013). Although some research has focused on the usage of tabletops within realistic conditions (Kharrufa et al., 2013; Martinez-Maldonado, Clayphan, & Kay, 2015), most of these studies have explored how tabletop-captured data can enhance teacher's class management activities. Nonetheless, there is a lack of explorations of the effect visualizations of tabletop-captured data can have on students' self-reflection process.

Additionally, several initiatives in the field of learning analytics have explored the analysis of students' collaboration data in distributed settings (Anaya, Luque, & Peinado, 2015; Charleer, Klerkx, Santos Odriozola, & Duval, 2013; Wise, Zhao, & Hausknecht, 2013). Most of this work has focused on using the analysis to: engage students in reflection about their learning process (Anaya et al., 2015), and help students and educators gain in-line awareness of group activities (Charleer et al., 2013). However, to our knowledge no research in the field of learning analytics has explored how automatically captured data can impact students' reflections of their collaborative skills.

In this study we examined how frequent exposure to an automatic tabletop-generated feedback can impact students' collaborative skills over time by facilitating students' self-reflection process. More specifically, we investigated the following three aspects: the impact of frequent on-time mixed (automatic and human-based) feedback of tabletop-supported group work on students' collaborative skills; the impact of frequent on-time mixed (automatic and human-based) feedback of tabletop-supported group work on students' self-s of their collaborative skills; and, the level of similitude between a tabletop-generated assessment of students' contributions to group work and a human-based assessment. In order to explore these questions, we compared the results obtained from groups using a tabletop application to design software versus groups using a paper-based approach for the same task.

Our findings show that the students that were exposed to frequent mixed feedback do not exhibit different levels of group work skills from those that received human-based feedback only. Similarly, students' self-perception of their levels of group work skills were not different between the two conditions. Nonetheless, students' self-perception of their levels of group work skills, improved significantly over the whole experience in both groups. Moreover, students exposed to frequent mixed feedback showed an improvement of their ability to communicate to other team members. This indicates that tabletop-generated on-time feedback has potential to enhance the development of students' communication skills in collaborative tasks. Interestingly, a positive moderate correlation between the automatic and human assessment of students' contributions to group work was found. This confirms opportunities to further explore tabletop-based assessment for group work activities

This paper is structured as follows: first, a related work section is presented and the proposed multi-touch tabletop application is described. Then, the research context, experiments and corresponding results are detailed. Finally, a discussion section along with reflections about further research is proposed.

Related Work

The emerging field of learning analytics is concerned with understanding and improving learning through the measurement, collection, analysis and reporting of data about learners and their contexts (Clow, 2012). One relevant challenge of research in the area is how to capture and offer effective visualizations of meaningful traces of learning. Work addressing this challenge usually focuses on using interviews and usability questionnaires to evaluate the potential of the proposed visualization (Anaya et al., 2015; Charleer et al., 2013; Clayphan et al., 2013; Martinez-Maldonado et al., 2013). A different challenge for learning analytics is how to place these visualizations in the context of learning, so that teachers and/or students can make reflective decisions based on the analytics. Existing work on this challenge has taken two different paths: one path draws from educational theories and suggests approaches for enhancing the effectiveness of learning analytics projects (Clow, 2012; Harfield, 2014); the other path explores what learning analytics can do for participants in realistic environments over the course of time (Martinez-Maldonado et al., 2015; McNely, Gestwicki, Hill, Parli-Horne, & Johnson, 2012). This paper focuses on this latter path: it seeks to explore how having students regularly engaging with their own data and goals can impact their activities and behaviors.

Exploring students' collaborative actions is a problem area of interest within the field of learning analytics. Previous work on collaboration analytics has mainly focused on distributed learning settings, generating automatic context-aware recommendations for students to improve their collaboration process (Anaya et al., 2015), and proposing personal dashboards and visualizations to support students' awareness of achievements and progress (Charleer et al., 2013). In general, learning analytics of students interacting in distributed settings often ignores that students can interact face-to-face or via other media (e.g., emails) (Charleer et al., 2013; McNely et al., 2012). Although our research pursues similar goals than previous explorations on collaborative analytics of distributed interactions, we focus specifically on studying learning analytics in the context of co-located collaboration.

Previous research on tabletops indicates this technology has the potential to enhance face-to-face collaborative learning; tabletops can encourage higher-level thinking and motivate effective learning (Kharrufa, Leat, & Olivier, 2010), elicit a more productive collaboration (Schneider et al., 2012), and support equitable participation in learning situations (Wallace et al., 2013). Furthermore, tabletops' ability to capture traces of students' interactions creates opportunities for studying co-located learning analytics. Relevant initiatives in the area have exploited tabletop-captured data for purposes such as: understanding the impact of users' territoriality around the tabletop (Tang, Pahud, Carpendale, & Buxton, 2010), capturing and analyzing collaborative multimodal data to distinguish the level of collaboration of student groups (Martinez-Maldonado et al., 2013), and helping educators manage their classrooms (Martinez-Maldonado et al., 2015). Little research on face-to-face learning analytics has directly identify students as target users; Clayphan et al. (2013) studied the potential of tabletop-generated feedback to engage students in reflection on their individual and group performance. However, this author's research did not focus on understanding the impact of feedback over time. Furthermore, very few studies have explored tabletop applications for realistic usage scenarios, with tasks that are meaningful for both students and educators (Martinez-Maldonado et al., 2015). In contrast, the present research examines the over-time impact of face-to-face learning analytics on students, and proposes a within-the-classroom approach where participants are studied while engaging in a task of their interest (software design).

System Description

The system used for this study was a projectable multi-touch tabletop system developed to support the collaborative design of normalized-logical database models (Granda, Echeverria, Chiluiza, & Wong-Villacres, 2015). Some of the hardware component include: 1) An Optitrack Motion Tracking System, 2) A Pico projector for presenting the image of the system, 3) Up to our 3D-printed pens with infrared markers at the top, 4) Tablets. The software components are: 1) A motion tracking server system, 2) A user-interface component and 3) A web application component. Fig 1 shows an overview of the implemented solution.

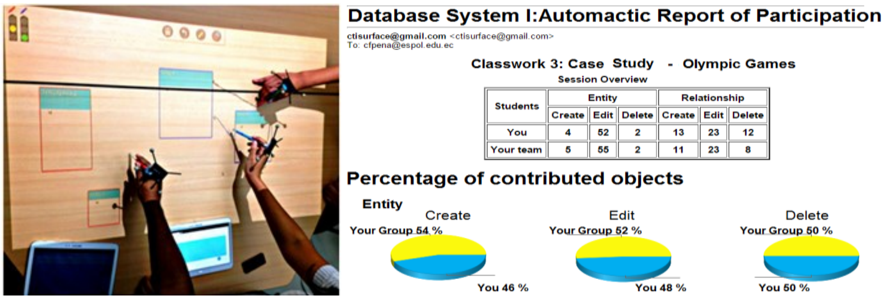

Figure 1. Students using the tabletop system and sample of student feedback.

Students interact with the system using pens and tablets. At any time, the motion server tracking system uses the Optitrack infrared-camera to identify markers of user's pens. Each pen has a unique configuration of 3 infrared markers. The position of the pen tip is calculated and delivered to the user-interface component via TUIO multi-touch protocol. The user interface draws traces based on touch points from the tracking server component. Additionally, this component recognizes the shape of pen traces drawn on the canvas: if a trace with the shape of a rectangle is recognized then the trace is replaced with the shape of an Entity within the database design; if a line between Entities is drawn, a Relationship replaces the trace instead. Text input is enabled by a web component system used on tablets.

Information about each student's activity on the tabletop (creation, edition and deletion of entities and relationships) is automatically captured. After a design session, the system sends an automatic performance report to each student's e-mail. The report describes her contribution to the task displaying the following information: the number and percentages of entity and relationship-related actions performed by the student (create, modify, delete); the number and percentages of actions performed by the rest of the group. A pie-chart representation was chosen given the exploratory nature of this study. Figure 1 presents relevant sections of a typical system report.

Methodology

Based on our review of previous work, we formulated three research questions: RQ1, do students repeatedly exposed to an automatic and human-based feedback of their group work performance exhibit a significant improvement on their collaborative skills compared to students who only received a human-based feedback? RQ2, do students repeatedly exposed to an automatic and human-based feedback of their group work performance perceive a greater change in their collaborative skills compared to students who only received a human-based feedback? RQ3, are there similarities between a tabletop-generated assessment of individuals' contributions to group work and a human-based assessment?

This study was conducted during the summer of 2015 at an Ecuadorian public university. It involved the participation of 21 undergraduate students enrolled in a Database System course of a Computer Science (CS) program (20 male and 1 female). An adapted version of the Readiness for Interprofessional Learning Scale (RIPLS) (Parsell, Bligh, & others, 1999) that included only the items related to teamwork and collaboration was used to form homogeneous groups. As a result, seven groups of three students were formed.

For this study, a two-group design was chosen. Students were randomly assigned to groups considering the results obtained in RIPLS. Three groups were assigned to the control condition and four to the experimental condition. The experiment consisted of three sessions. Session 1 and 2 took place the same day, and session 3 a week later. In each session, groups were assigned a database design problem; while the control group performed the activity using paper and markers and received human-based feedback only, the experimental group used the previously described tabletop application, receiving both, human-based and automated feedback. These activities were carried out after the midterm evaluation to allow for students to practice on Database Design topics already reviewed during the first part of the term. The instructor did not interact with the students during the tasks; he only provided formative feedback on the end result of the exercise.

During each session, a trained observer assessed each student's group work skills. This provided us with the information needed to acknowledge any changes in individual's performance over time. In order to gauge collaboration we derived the following dimensions both from previous work on the area (Buisine et al., 2012; Meier, Spada, & Rummel, 2007) and from the university's expectations of group work skills: contributions (student verbal and physical useful contributions to the team's goal), communication (student verbal expressions and physical gestures used to let the team know his/her opinion to other team members) and respect (student verbal and physical demonstrations of respect towards others opinions and actions). The observers had to total the number of actions according to the dimensions. Observers' results were later transformed to a 0 to 2 scale: 0 if the performance of the student on a dimension did not meet the expectations, 1 if the expectation was fulfilled partially and 2 if it was completely fulfilled. Even though a wider scale could better support fine-grained ratings, the 0 to 2 scale was chosen to facilitate the assessment for the observer; due to the duration of each session, more complex methods with more cognitive load could have a negative impact on the observer's assessment ability.

Immediately after each session, students were asked to use the same dimensions to assess their peers' group work skills as well as their own, using the 0 to 2 scale. Additionally, the tabletop system sent the automatic generated report previously described, to students in the experimental group. Within three days after each session, all students received: a summary report comparing their self-assessment with both their observer's and group members' assessment (Figure 2); and guided questions to prompt a reflective writing on their group work abilities. The questions attempted to engage students in describing the activities carried out during the task, the obstacles found, their perception on the received feedback, and the actions students planned to take in order to improve their collaborative skills for the next group activity. For the final reflection, guided questions focused on prompting students to reconsider their initial self-assessments as well as on gauging students' perception of the tabletop usefulness. Tabletop usefulness was measured from 1 to 5, being 1: no useful and 5: very useful.

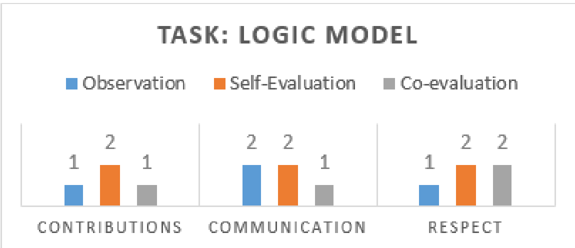

Figure 2. Information displayed in students' report.

Results

The results were analyzed comparing the assessment data gathered between session 1 and 3 related to the three previously established group work dimensions: *contributions, communication and respect.* Descriptive results from student's evaluation show that a positive effect was observed on the *contribution* and *communication* dimensions: Session 1 (*Contributions* and *Communication: median=1, Respect: median=2*). In Session 2 all dimensions reported (median=1); In Session 3 (*Contributions* and *Communication: median=2, Respect: median=1*).

Regarding RQ1: *Do students repeatedly exposed to an automatic and human-based feedback of their group work performance exhibit a significant improvement on their collaborative skills compared to students who only received a human-based feedback?* A Mann-Whitney U test was employed. The results showed no significant differences in all group work dimensions (*Contributions* $U=56.0$ $W=101.0$ $p>0.05$; *Communication* $U=56.6$ $W=101.5$ $p>0.05$; *Respect* $U=29.5$ $W=74.5$ $p>0.05$). Additionally, tests for intra-group differences were performed for all dimensions. A positive effect was observed in the communication dimension of the experimental group between session 1 (median=1) and session 3 (median= 2) ($Z=49.5$, $p<0.011$) whereas, the *Respect* dimension of the control group exhibited a negative effect ($Z=0.0$, $p<0.020$) between session 1 (median=2) and session 3 (median=1).

Regarding RQ2: *Do students repeatedly exposed to an automatic and human-based feedback of their group work performance perceive a greater change in their collaborative skills compared to students who only* *received a human-based feedback?* No significant differences were found in any of the dimension between both conditions when using Mann-Whitney U Test (*Contributions* $U=28.5$ $W=73.5$ $p>0.05$; *Communication* $U=34.0$ $W=79.0$ $p>0.05$; *Respect* $U=34.0$ $W=70.0$ $p>0.05$). Additionally, tests for intra-group differences were performed for all dimensions. A positive effect was observed in the *Contributions* dimension of both the experimental and control group between session 1 and session 3 (experimental group: session 1 *median*=1, session 3 *median*= 2, $Z=28.0$ $p<0.008$; control group: session 1 *median*=1, session 3 *median*= 1, $Z=10.0$ $p<0.046$).

Regarding RQ3: *Are there similarities between a tabletop-generated assessment of individuals' contributions to group work and a human-based assessment?* A Kendall Tau correlation test was performed for each session. In session 1 no significant correlation was found ($rt=0.254$, $p= 0.368$), in session two a moderate correlation was observed, though not significant ($rt=0.4$, $p=0.213$). Finally, in session three a moderate significant correlation was found ($rt=0.613$, $p =0.030$). As it can be seen, an increasing trend in the correlations over time is observed too.

Furthermore, feedback about students' perception of the tabletop usefulness was gathered. The results obtained were mixed (median=3), meaning that the solution was perceived as "useful". Moreover, qualitative feedback was also collected. Some comments about the solution were positive, for example: "*..The solution seems interesting to me because, this uses a new way to interact with technology..*". Whereas some students reported: "*.. I do not see why using this technology..*"

Discussion and Further Work

This study examined the potential of over-time exposure to automatic tabletop-generated feedback on students' collaborative skills. Results indicate that groups that received mixed feedback do not differ in their group work abilities when compared to those that received human-based feedback only. Similarly, students' self-perception of their group work abilities was not different between the two conditions. Nonetheless, students' self-perception of their collaborative skills, improved significantly over time on both the tabletop and the paper-based conditions. Moreover, communication skills during group work activities for the tabletop condition showed an improvement over time. These results are in line with the findings of Buisine et al. (2012), who underlined that tabletop led to more communicative gestures and more distributed verbal contributions than a paper-based approach.

Additionally, the results showed that, over time, students who did not receive any exposure to the tabletop feedback decreased their level of respect to their peers. Previous studies have concluded that pen-based interactions on a tabletop enhance group members' awareness of others (Jamil, O'Hara, Perry, Karnik, & Subramanian, 2011); and that the presence of colored indicators to distinguish ownership of creation in tabletop systems triggers social comparison and awareness (Buisine et al., 2012). Overall, social awareness could promote respectful interactions amongst group members; the lack of features that enhance awareness of others could explain the decrease in the respect dimension of the paper-based group. Furthermore, receiving continuous tabletop-generated feedback comparing individual's group work performance to the rest of the groups can augment individuals' awareness of their peers. Therefore, another possible reason for students in the paper-based condition to decrease their levels of respect is the lack of tabletop-generated feedback. It is also important to note that this research's results pertaining the level of similitude between an automatic assessment *of individuals' contributions to group work and a human-based assessment* show a positive moderate correlation between both assessments. Moreover, qualitative feedback showed that this tool is promising due to the usefulness reported by students. This confirms opportunities to further explore tabletop-based assessment for group work activities.

Nonetheless, it is relevant to consider the following confluent variables that could have affected the results of the experiment: 1) the novelty effect of using a tabletop could have changed student's behavior during the first session in terms of mutual respect and communication; 2) usability issues hindered students' abilities to seamlessly execute the tasks they intended, causing them to experience communication breakdowns; 3) the design of the automatic feedback heavily based on pie charts could have been ineffective to encourage students' understanding of the data; 4) the possible bias of using only one observer on a group of three to four students could have had a strong impact on the assessments. Future work on this area must consider a different design for the automatic feedback, as well as recording the sessions so that at least two observers have the opportunity to evaluate the groups. Finally, it is relevant to conclude that more research is needed to find the precise effect of on-time feedback by tabletop systems on collaborative skills of students.

References

Al-Qaraghuli, A., Zaman, H. B., Olivier, P., Kharrufa, A., & Ahmad, A. (2011). Analysing tabletop based

computer supported collaborative learning data through visualization, 329–340.
Anaya, A. R., Luque, M., & Peinado, M. (2015). A visual recommender tool in a collaborative learning experience. *Expert Systems with Applications*, *45*(C), 248–259. http://doi.org/10.1016/j.eswa.2015.01.071
Buisine, S., Besacier, G., Aoussat, A., & Vernier, F. (2012). How Do Interactive Tabletop Systems Influence Collaboration? *Comput. Hum. Behav.*, *28*(1), 49–59. http://doi.org/10.1016/j.chb.2011.08.010
Charleer, S., Klerkx, J., Santos Odriozola, J. L., & Duval, E. (2013). Improving awareness and reflection through collaborative, interactive visualizations of badges. In *ARTEL13: Proceedings of the 3rd Workshop on Awareness and Reflection in Technology-Enhanced Learning* (Vol. 1103, pp. 69–81). CEUR-WS.
Clayphan, A., Martinez-Maldonado, R., & Kay, J. (2013). Designing OLMs for Reflection about Group Brainstorming at Interactive Tabletops. In *Workshop on Intelligent Support for Learning in Groups (ISLG) - International Conference on Artificial Intelligence in Education (AIED 2013)* (Vol. 1009).
Clow, D. (2012). The learning analytics cycle: closing the loop effectively. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 134–138).
Dekel, U., & Herbsleb, J. D. (2007). Notation and Representation in Collaborative Object-oriented Design: An Observational Study. *SIGPLAN Not.*, *42*(10), 261–280. http://doi.org/10.1145/1297105.1297047
Dillenbourg, P. (1999). What do you mean by collaborative learning? *Collaborative-Learning: Cognitive and Computational Approaches.*, 1–19.
Falcão, T. P., & Price, S. (2011). Interfering and resolving: How tabletop interaction facilitates co-construction of argumentative knowledge. *International Journal of Computer-Supported Collaborative Learning*.
Granda, R. X., Echeverria, V., Chiluiza, K., & Wong-Villacres, M. (2015). Supporting the Assessment of Collaborative Design Activities in Multi-tabletop Classrooms. In *2015 Asia-Pacific Conference on Computer Aided System Engineering* (pp. 270–275). IEEE. http://doi.org/10.1109/APCASE.2015.54
Harfield, T. D. (2014). Teaching the Unteachable: On the Compatibility of Learning Analytics and Humane Education. In *Proceedings of the Fourth International Conference on Learning Analytics And Knowledge* (pp. 241–245). New York, NY, USA: ACM. http://doi.org/10.1145/2567574.2567607
Jamil, I., O'Hara, K., Perry, M., Karnik, A., & Subramanian, S. (2011). The effects of interaction techniques on talk patterns in collaborative peer learning around interactive tables. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3043–3052).
Kharrufa, A., Balaam, M., Heslop, P., Leat, D., Dolan, P., & Olivier, P. (2013). Tables in the wild. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13* (p. 1021). New York, New York, USA: ACM Press. http://doi.org/10.1145/2470654.2466130
Kharrufa, A., Leat, D., & Olivier, P. (2010). Digital Mysteries: Designing for Learning at the Tabletop. In *ACM International Conference on Interactive Tabletops and Surfaces* (pp. 197–206). New York, NY, USA: ACM. http://doi.org/10.1145/1936652.1936689
Lee, J., Kotonya, G., Whittle, J., & Bull, C. (2015). Software Design Studio: A Practical Example. In *2015 IEEE/ACM 37th IEEE International Conference on Software Engineering* (Vol. 2, pp. 389–397). IEEE. http://doi.org/10.1109/ICSE.2015.171
Martinez-Maldonado, R., Clayphan, A., & Kay, J. (2015). Deploying and Visualising Teacher's Scripts of Small Group Activities in a Multi-surface Classroom Ecology: a Study in-the-wild. *Computer Supported Cooperative Work (CSCW)*, *24*(2-3), 177–221. http://doi.org/10.1007/s10606-015-9217-6
Martinez-Maldonado, R., Dimitriadis, Y., Martinez-Monés, A., Kay, J., & Yacef, K. (2013). Capturing and analyzing verbal and physical collaborative learning interactions at an enriched interactive tabletop. *International Journal of Computer-Supported Collaborative Learning*, *8*(4), 455–485. http://doi.org/10.1007/s11412-013-9184-1
McNely, B. J., Gestwicki, P., Hill, J. H., Parli-Horne, P., & Johnson, E. (2012). Learning analytics for collaborative writing. In *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge - LAK '12* (p. 222). New York, New York, USA: ACM Press. http://doi.org/10.1145/2330601.2330654
Meier, A., Spada, H., & Rummel, N. (2007). A rating scheme for assessing the quality of computer-supported collaboration processes. *International Journal of Computer-Supported Collaborative Learning*, *2*(1).
O'Donnell, A. M. (2006). The Role of Peers and Group Learning. In L. E. Associates (Ed.), *Handbook of educational psychology* (pp. 781–802). Lawrence Erlbaum Associates Publishers.
Parsell, G., Bligh, J., & others. (1999). The development of a questionnaire to assess the readiness of health care students for interprofessional learning (RIPLS). *Medical Education*, *33*(2), 95–100.
Schneider, B., Strait, M., Muller, L., Elfenbein, S., Shaer, O., & Shen, C. (2012). Phylo-Genie: Engaging Students in Collaborative "Tree-thinking" Through Tabletop Techniques. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3071–3080). New York, NY, USA: ACM.

http://doi.org/10.1145/2207676.2208720
Tang, A., Pahud, M., Carpendale, S., & Buxton, B. (2010). VisTACO: Visualizing Tabletop Collaboration. In *ACM International Conference on Interactive Tabletops and Surfaces* (pp. 29–38). New York, NY, USA: ACM. http://doi.org/10.1145/1936652.1936659
Wallace, J. R., Scott, S. D., & MacGregor, C. G. (2013). Collaborative sensemaking on a digital tabletop and personal tablets: prioritization, comparisons, and tableaux. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3345–3354).
Xambó, A., Hornecker, E., Marshall, P., Jorda, S., Dobbyn, C., & Laney, R. (2013). Let's jam the reactable: Peer learning during musical improvisation with a tabletop tangible interface. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *20*(6), 36.
Zhang, D., Zhao, J. L., Zhou, L., & Nunamaker Jr., J. F. (2004). Can e-Learning Replace Classroom Learning? *Commun. ACM*, *47*(5), 75–79. http://doi.org/10.1145/986213.986216

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